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ANALYSIS OF NAVY HORNET SQUADRON MISHAP COSTS WITH REGARD TO PREVIOUSLY FLOWN FLIGHT HOURS

by

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June 2017

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13. ABSTRACT (maximum 200 words)

Naval aviation is inherently dangerous. Recently, budgetary pressures have reduced flight hours across naval aviation. The author's experience as a naval aviator has allowed him to see that mishaps occur more frequently in a squadron when flight hours are reduced. This thesis correlates F/A-18 Hornet and Super Hornet squadron previously flown flight hours with mishap costs. It uses a macro level approach by evaluating how a squadron's previously flown flight hours affect mishap cost and the likelihood of a mishap. This thesis does not attempt to assign mishap causality; this thesis describes only the relationship between mishap cost and previously flown flight hours.

Analyzing 15 years' worth of squadron monthly flight hours and mishaps shows that mishap cost is statistically correlated to the flight hours flown during the previous three and six months. A linear multivariate model was developed and used to analyze a dataset containing mishaps in the years 2001–2016. This analysis showed a reduction of ~$9,500 in mishap cost for every flight hour flown in the previous three months. Additionally, mishap rates were shown to increase during periods of low flight-hour operations. Cost per flight hour is approximately $10,000, making a mishap cost increase (when a mishap occurs) from a reduction in flight hours roughly equal to the cost per hour.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGM	Aviation Ground Mishap
BCA	Budget Control Act
CPH	Cost per Hour
CSAS	Command Safety Assessment Survey
DECKPLATE	Decision Knowledge Programming for Logistics Analysis and Technical Evaluation
DOD	Department of Defense
DON	Department of Navy
FM	Flight Mishaps
FOIA	Freedom of Information Act
FRM	Flight Related Mishaps
FRS	Fleet Replacement Squadron
JIC	Joint Inflation Calculator
MCAS	Maintenance Climate Assessment Survey
NATOPS	Naval Air Training and Operating Procedures Standardization
NPS	Naval Postgraduate School
NSAWC	Naval Strike and Air Warfare Center
NSC	Naval Safety Center
PCF	Pilot Causal Factor
ORM	Organizational Risk Management
SMS	Safety Management System
THD	Tactical Hard Deck
T&R	Training and Readiness
UAV	Unmanned Aerial Vehicle

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I would like to thank my wife, Jessica Baumann, for being the foundation of our family.

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I. INTRODUCTION

A. BACKGROUND

Ever since Eugene Ely's first flight on November 14, 1910, mishaps have been part of doing business in naval aviation. Ely's first dive off of a converted light cruiser nearly resulted in disaster as his wheels dragged in the water before his Hudson Fulton Flyer rose from the surface and shortly landed on a nearby beach (Moore, 1981). Over the course of its history, the U.S. Navy has learned to minimize the risks inherent in naval aviation. Angled flight decks, standardization programs, and the fleet-wide implementation of risk management programs are only a few examples of successful mishap mitigation programs that naval aviation has utilized. Currently, mishaps in naval aviation stand near historical lows. However, the most severe U.S. Navy aircraft mishaps did increase in 2014 and 2015, while the Marine Corps saw a similar increase in 2015 and 2016 (Naval Safety Center, 2016). These increases represent a disturbing reversal of a long-term mishap reduction trend.

The Budget Control Act (BCA), passed on August 1, 2011, has required the Department of Defense (DOD) to make difficult decisions regarding defense spending (Belasco, 2015). The Department of the Navy (DON) has been forced to reduce flight hours for non-deployed Hornet and Super Hornet squadrons, which negatively affects readiness. According to Admiral Michelle Howard, "Navy readiness is at its lowest point in many years … which can be attributed chiefly to budget reductions" (The Heritage Foundation, 2016, p. 240). It is within this difficult fiscal environment that the Navy has been continuing to deploy around the world and operate its aircraft.

For non-deployed F/A-18 pilots this budgetary pressure results in fewer flying hours. Rear Adm. Mike Manazir told the House Armed Services Tactical Air and Land Forces Subcommittee that a significant number of non-deployed assets are flying fewer hours than needed for readiness goals (Eckstein, 2016). The Navy sets a minimum number of pilot flight hours per month, called a Tactical Hard Deck (THD), of 11 hours per month; this is a reduction from a normal 16 hours for a non-deployed pilot (Eckstein,

2016). Manazir points out that below the THD flying level, they are not “proficient and current enough to remain safe in the airplane” (Eckstein, 2016, para. 15).

1. Mishaps

The DON promulgates the 2014 OPNAV Instruction 3750.6S, which details the Naval Aviation Safety Management System (SMS). This instruction is used by both the Navy and the Marine Corps to “detect, contain, or eliminate hazards in naval aviation.” (Department of the Navy [DON], 2014, p. 1–1) The Navy defines a mishap as an unplanned event that results in damage, illness, or personal injury to both aircraft and Unmanned Aerial Vehicles (UAV). Naval aviation mishaps are organized according to classification and severity. There is a $20,000 reporting threshold for all naval aviation mishaps (DON, 2014). Naval aviation mishaps are broken down into four categories based upon their severity level: class A, class B, class C, and class D. Of these, class A mishaps are the most severe.

2. Navy and Hornet Squadron Organization

This study utilizes the squadron flight hours and sorties flown in months prior to a mishap as independent variables. A discussion of a typical Navy Hornet squadron’s organization is needed to elaborate why squadron flight hours and sorties are important metrics. Figure 1shows a generic Navy Hornet squadron organizational chart.

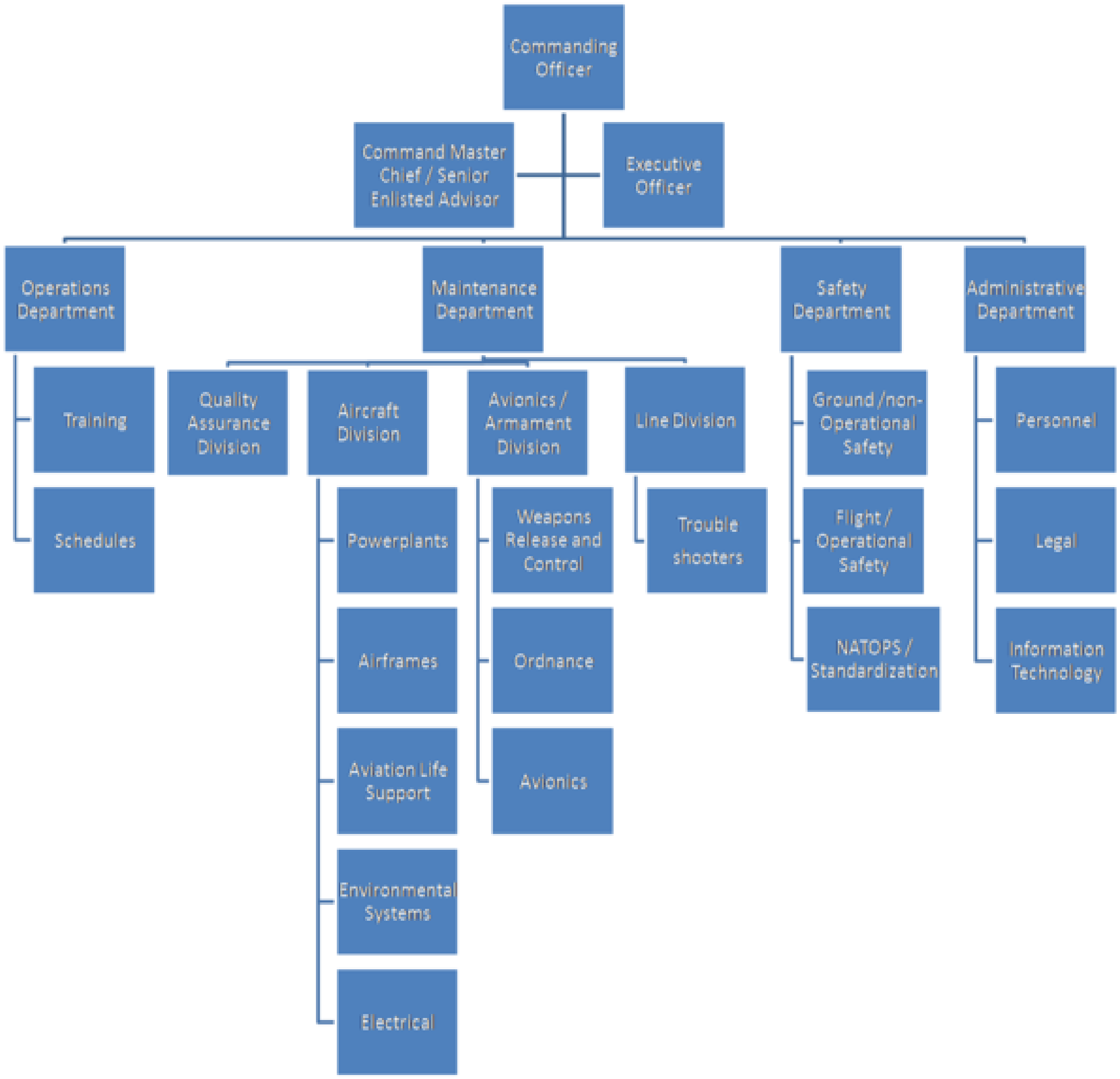

Figure 1 Generic Navy Hornet Squadron Organizational Chart.
Source: (DON, 2012).

A typical Navy Hornet squadron comprises approximately 20 officers and 200 enlisted personnel. It is organized into four departments: maintenance, operations, safety, and administration. The maintenance department is tasked with maintaining the aircraft and ensuring that they are safe for flight and mission capable. The maintenance department and the pilots are the primary personnel interacting with the squadron’s aircraft. The maintenance department handles all operational level (O-level) maintenance to include preventative work, repair work, and routine checks. There are approximately 10 officers and 180 enlisted personnel assigned to the maintenance department. The

operations department is tasked with current and future operations of the squadron including the daily flight schedule and future deployments. The Safety department ensures that the squadron is adhering to safety instructions and is responsible for reporting any mishaps to the Naval Safety Center (NSC). The administration department handles all administrative tasks including travel, enlistments, discharges, and evaluations (DON, 2012).

Navy Hornet squadrons act as a cohesive unit. An increase in flight hours means more work for everyone, from the most senior pilot to the most junior airman. Similarly, the author has observed that a decrease in monthly flight hours means that skills have the chance to atrophy. While there is more time for maintenance on the aircraft, during periods of reduced flight activity, the skills needed to safely launch and recover aircraft are not used to their full extent and have a chance to diminish. Mishaps that occur on the ground are most likely to be the result of an accident by the Maintenance department and are typically not as severe as flight related incidents. Airborne mishaps and mishaps that occur when there was intention to fly can be the result of either an incorrect pilot action or the result of improper maintenance. These airborne mishaps generally are more severe and can take the form of loss of aircraft or loss of life.

The primary means for the Navy to ensure that a squadron is ready for deployment is to allocate more flight hours to ensure a squadron meets its readiness goals (DON, 2010). As a squadron comes closer to deployment, the Navy allocates more flight hours to that squadron. However, due to the recent budgetary pressures outlined above, squadrons that are not near deployment have seen their flight hours cut, sometimes dramatically. Some squadrons have seen extended periods of flying at the THD, while others have been shut down for months. This flight-hour cut affects not only the pilot's proficiency, but also the maintainer's proficiency. This study will look at the effects of changes in flight hours upon the entire squadron. The author has observed that all elements of a squadron are affected by a change in flight hours.

B. PURPOSE OF THE STUDY

This study evaluates any correlation between previously flown monthly flight hours and mishap cost. This information can be used to allot squadron flying hours more efficiently in an effort to reduce cost. The study uses multivariable linear regression to determine statistically significant independent variable effects on mishap cost, the dependent variable. The experimental hypothesis is that a squadron’s previously flown monthly flight hours are statistically related to mishap cost.

C. RESEARCH QUESTIONS

This study focuses on a primary and two secondary research questions.

1. For Navy Hornet Squadrons, are past flight-hours flown correlated to mishap costs per squadron?

If so:

2. What is the correct lag structure? (i.e., how many months back should flight hours aggregate to provide the strongest correlation?)
3. What are the financial and operational implications of decreases in squadron monthly flight hours to the Department of the Navy?

D. SCOPE

This study is limited to a comparative analysis between monthly flight hours and mishap cost for Navy Hornet and super Hornet squadrons. Only operational squadrons were evaluated in an effort to compare similar squadron utilization and size. The time frame evaluated was from September 1, 2001–August 31, 2016. Only class A/B/C mishaps were included in the study. The study looks at the squadron activity as a whole and does not take into account causal factors of a mishap. This study does not include any Marine Corps Hornet squadrons, training squadrons, or other types of aircraft other than Navy F/A-18 Hornets and super Hornets.

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II. LITERATURE REVIEW

A. OVERVIEW

Mishaps are a fact of life in naval aviation. Since the Navy started flying aircraft, it has been working to reduce the number and cost of mishaps. Improvements such as angled flight decks on aircraft carriers and the Naval Air Training and Operating Procedures Standardization (NATOPS) program have greatly reduced the rate of mishaps in naval aviation (DON, 2014). There are more studies and journal articles written about naval aviation than can be covered in this study. Additionally, the fields of accident prevention and task learning are relevant to this study. Below are some highlights from the literature.

B. PREVIOUS ATTEMPTS TO CORRELATE MISHAPS IN NAVAL AVIATION

Multiple attempts have been made to reliably correlate Naval Aviation mishaps with an indicator variable. This literature review looked at three areas of study: a reduction in flying hours, human factors data, and squadron survey results.

1. Reduced Flying Activity

In 2013, Edward Hobbs of the NSC showed that class B flight mishap rates increased for Hornet squadrons experiencing a period of reduced flying hours. Hobbs utilized monthly flight hour information from the Navy's maintenance server and evaluated when Hornet squadrons were in a period of reduced flying hours. A period of reduced flying hours was calculated using a 95 percent level for each squadron. Then mishap rates were calculated for both normal operations and periods of reduced flying hours. These mishap rates were then subject to a 95 percent confidence threshold and only class B flight mishaps were shown to be statistically increased during periods of reduced flight hours. Hobbs' data set included only operational Navy Hornet and super Hornet squadrons from FY91 to FY 10 (Hobbs, 2013). The study did not include any cost data or analysis.

2. Human Factors

Human factors are probably the most researched topic with regards to naval aviation mishaps with particular emphasis on physiological factors related to accidents. Borowsky (1986) found that as a Navy pilot's career experience increased the mishap rate decreased. His study only evaluated pilot error, but was significant in that it showed a relationship between pilot error mishaps and hours flown in model of aircraft. The relationship of mishap rate to hours flown in total and in model found by Borowsky can be seen in Table 1.

Table 1 Class A Flight/Flight Related Pilot Error Mishap Rate per 100,000 Flight Hours. Source: Borowsky (1986).

		Hours in Model				
		0-300	**301-500**	**501-1000**	**1000+**	**Total**
Total Hours	**0-450**	9.99	-	-	-	9.99
	451-750	9.62	4.41	-	-	6.75
	751-1500	3.94	4.20	4.07	0	3.72
	1500+	2.27	5.04	5.78	3.65	4.14
	Total	6.35	4.54	4.82	3.26	4.95

After the implementation of Organization Risk Management (ORM) at the Naval Strike and Air Warfare Center (NSAWC) in Fallon, Nevada there was a statistically significant reduction in human factors mishaps (Belland et al., 2010). Belland and his co-authors were not able to completely attribute the reduction to the implementation of ORM, but were able to show a statistically significant decrease in mishaps after its implementation. Based on the results of these two studies, human factors relating to flight hours can affect the mishap rate in naval aircraft.

3. Surveys

Safety surveys have been shown to be both a leading and lagging indicator of accidents in process industries (Payne et al., 2010). Additionally, among employees three aspects were demonstrated to be strongly related: perceptions of a clean work environment, perceptions of whether safety issues were addressed quickly, and stress levels (Payne et al., 2010). Similarly, a survey in the U.S. nuclear industry found that a safety survey could be correlated to safety performance (Morrow et al., 2014). However, the authors emphasize that surveys can be but one potential indicator of an organizations safety culture and likelihood of an accident (Morrow et al., 2014). When evaluating the safety climate of an organization, surveys are a useful tool, but should not be the sole metric (Morrow et al., 2014).

Unfortunately, current safety surveys in naval aviation have not been shown to correlate or be adequately constructed to predict safety incidents in naval aviation. In 2011, a Naval Postgraduate School (NPS) thesis attempted to correlate whether the Navy's Command Safety Assessment Survey (CSAS) could be correlated to mishaps that occurred in the command (O'Connor et al., 2011). The study found only a weak and unreliable correlation between results from the CSAS and a squadron's potential for a mishap. Similarly, the Maintenance Climate Assessment Survey (MCAS) was found to be an ineffective tool to predict mishaps due to its organization and structure (Brittingham, 2006). Instead, it is the opinion of the author, that only maintenance data should be utilized in order to evaluate mishap potential.

C. MAINTENANCE DATA

An attempt was made in 1994 by another NPS student to forecast mishaps using monthly maintenance reports. The data included flight hours, sorties, and maintenance man-hours for Marine Corps squadrons (Van Houten, 1994). There was not found to be any relationship at the time between the then-year monthly maintenance reports and aircraft mishaps (Van Houten, 1994).

D. LEARNING AND FORGETTING

In order to guide the methodology of this thesis, literature relating to how people and organizations gain and retain proficiency at tasks was evaluated. Research by Nembhard (2000) showed that task complexity is related to the ability to learn a task and the rate at which it will be forgotten. His work concluded that while experienced workers in the textile industry learn a new task faster than inexperienced workers, a similar amount of production occurs during steady state operations for both types of workers. Additionally, experienced workers also forget new tasks faster than inexperienced ones. In essence experienced workers are more adaptable to change; however, for steady state operations experience plays a minimal impact in overall performance. This data may be applicable to Navy Hornet squadrons in that steady state operation could see a decrease in mishaps, while an increase and decrease in flight hours may lead to errors. Nembhard has shown that changes in operation (i.e., nonsteady-state operation) lead to mistakes and added time to accomplish tasks regardless of experience on an individual level.

This study looks at the squadron level relationship between recent experience and performance. The individual-level work that Nembhard has studied may be related, but may be obscured by the more macro approach of this thesis. Nevertheless, his research has laid a good foundation for examining how change in operation relates to performance, or in this thesis mishap rate and cost.

E. ACCIDENT FORECASTING METHODOLOGIES

This study evaluates not just whether or not a mishap occurred, but also correlates the total cost of the mishap to flight hours. Naval aviation mishap cost data evaluation is missing from the pertinent literature and this study attempts to fill that gap. Much of the pertinent literature either focuses on tools for prevention such as predictive surveys or an analysis of causal factors of a mishap. The NSC and the pertinent Center for Naval Analysis (CNA) studies all only evaluated mishap rate by class. While understanding how often different class mishaps occur is useful, a more thorough understanding of how severe a mishap is may yield interesting results. By analyzing mishap cost as another

surrogate for severity, this study seeks to be a tool for decision-makers to minimize the mishap costs associated with a Navy Hornet squadron.

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III. METHODOLOGY

A. RESEARCH APPROACH

The objective of this study is to provide decision makers with information regarding how the amount of flight hours a squadron flies per month correlates to mishap cost. This also includes an analysis of any indication of segments of increased mishap rate and the associated costs. The literature supports a connection between Pilot Causal Factor (PCF) mishaps and pilot flight hours, both career and recent (Smith & Brobst, 2010). This study looks at an entire squadron’s likelihood of a mishap based upon previously flown flight hours, not just at mishaps where human factors are found to be a causal factor. Data was collected from September 1, 2001–August 31, 2016, representing 15 years of Hornet and Super Hornet data.

B. OPERATIONAL SQUADRONS

The scope of this study is limited to operational Navy Hornet and super Hornet squadrons. This was done in an effort to evaluate squadrons with similar operational characteristics. The operational requirements of Fleet Replacement Squadrons (FRS) and Test and Evaluation squadrons do not lend themselves to a one to one comparison. Table 2 shows the 36 operational Hornet and Super Hornet squadrons whose data was evaluated and the series of Hornet or super Hornet flown by each squadron. Notably, some squadrons have more than one series because they transitioned from one series to another during the relevant timeframe.

Table 2 Hornet and Super Hornet Squadron Data Analyzed.

VFA-2 – F/A-18F	VFA-97 – F/A-18A/C/E
VFA-11 – F/A-18F	VFA-102 – F/A-18F
VFA-14 – F/A-18E	VFA-103 – F/A-18F
VFA-15 – F/A-18C	VFA-105 – F/A-18C/E
VFA-22 – F/A-18F	VFA-113 – F/A-18C/E
VFA-25 – F/A-18C/E	VFA-115 – F/A-18C/E
VFA-27 – F/A-18C/E	VFA-131 – F/A-18C
VFA-31 – F/A-18E	VFA-136 – F/A-18C/E
VFA-32 – F/A-18F	VFA-137 – F/A-18C/E/F
VFA-34 – F/A-18C	VFA-143 – F/A-18E
VFA-37 – F/A-18C	VFA-146 – F/A-18C/E
VFA-41 – F/A-18F	VFA-147 – F/A-18C/E
VFA-81 – F/A-18C/E	VFA-151 – F/A-18C/E
VFA-82 – F/A-18C	VFA-154 – F/A-18F
VFA-83 – F/A-18C	VFA-192 – F/A-18C/E
VFA-86 – F/A-18C/E	VFA-195 – F/A-18C/E
VFA-87 – F/A-18A/C/E	VFA-211 – F/A-18F
VFA-94 – F/A-18C/F	VFA-213 – F/A-18F

C. DETAILED MISHAP CLASSIFICATION

Mishap classifications separate events based upon whether there was intent for flight and whether there was any damage to a UAV or manned aircraft. The classifications are defined in OPNAV Instruction 3750.6S (2014, pp. 3–15 and 3–16):

> <u>Flight Mishaps (FM)</u>
>
> A mishap where there is intent for flight and reportable damage to a DOD aircraft or UAV or the loss of a DOD manned aircraft.
>
> <u>Flight-Related Mishaps (FRM)</u>
>
> A mishap where there is intent for flight and no reportable damage to the aircraft or UAV itself, but the mishap involves a fatality, reportable injury or reportable property damage.
>
> <u>Aviation Ground Mishap (AGM)</u>
>
> A mishap where there is no intent for flight that results in reportable damage to an aircraft or UAV, or death or injury involving an aircraft or UAV. This applies to both on land and on board ship. (DON, 2014)

D. MISHAP SEVERITY

Mishaps are separated by severity according to the total cost of damage and whether there was a destruction of aircraft or fatality. The mishap severities are defined in OPNAV Instruction 3750.6S (2014, pp. 3–14 and 3–15) as:

> <u>Class A</u>
>
> A class A mishap is one in which the total cost of damage to DOD or non-DOD property, aircraft, or UAVs is $2 million or more, or a naval aircraft is destroyed or missing, or any fatality or permanent total disability of personnel results from the direct involvement of naval aircraft or UAV.
>
> <u>Class B</u>
>
> A class B mishap is one in which the total cost of damage to DOD or non-DOD property, aircraft or UAVs is $500,000 or more, but less than $2 million, or results in a permanent partial disability, or when three or more personnel are hospitalized for inpatient care (which, for mishap reporting purposes only, does not include just observation or diagnostic care) as a result of a single mishap.
>
> <u>Class C</u>
>
> A class C mishap is one in which the total cost of damage to DOD or non-DOD property, aircraft or UAVs is $50,000 or more, but less than $500,000, or a nonfatal injury or illness that results in one or more days away from work, not including the day of the injury.
>
> <u>Class D</u>
>
> A class D mishap is one in which the total cost of damage to DOD or non-DOD property, aircraft or UAVs is $20,000 or more, but less than $50,000; or a recordable injury (greater than first aid) or illness results not otherwise classified as a class A, B, or C mishap. (DON, 2014)

E. HOW MISHAP COST IS CALCULATED

Total event cost for a mishap is calculated by adding up the complete property damage cost and injury costs. Property damage costs are delineated in OPNAVINST 3740.6S (2014), and include all damage to DOD and non-DOD property, spare part utilization, salvageable parts, maintenance man-hours, and inspection costs. Injury cost guidelines are delineated in OPNAVINST 5102.1D (2005) and are located in Appendix A. Total mishap cost thus includes all property damage and injury costs associated with

the mishap. Mishap costs have been normalized into FY 2015 Dollars using the Joint Inflation Calculator (JIC) February 2016 (NCCA, 2016).

F. DATA

In this section, I describe how the data used in my analysis was collected, and provide descriptive statistics relevant to my research questions.

1. Mishap Data Collected

Hornet and Super Hornet mishap data was obtained via a Freedom of Information Act (FOIA) request for all hornet and Super Hornet mishaps during the timeframe. Information provided in the FOIA request included:

4. Mishap Date
5. Mishap Squadron
6. Mishap Classification (FM/FRM/AGM)
7. Mishap Severity (A/B/C)
8. Total Mishap Cost
9. Type / Model / Series of Aircraft
10. Short Narrative of the Mishap

For the purposes of this study only Class A, B, and C mishaps were evaluated due to Class D mishaps being only recently introduced in 2011 (DON, 2014). The short narratives were not used in this study. Mishaps that occurred within three months of a squadron transitioning to a new series were not included in the analysis (e.g. F/A-18C to F/A-18E). This three-month period was placed in order to allow transitioning squadrons to gain a similar amount of experience in their new airframe as established squadrons. Figure 2 shows the total cost of all mishaps per year.

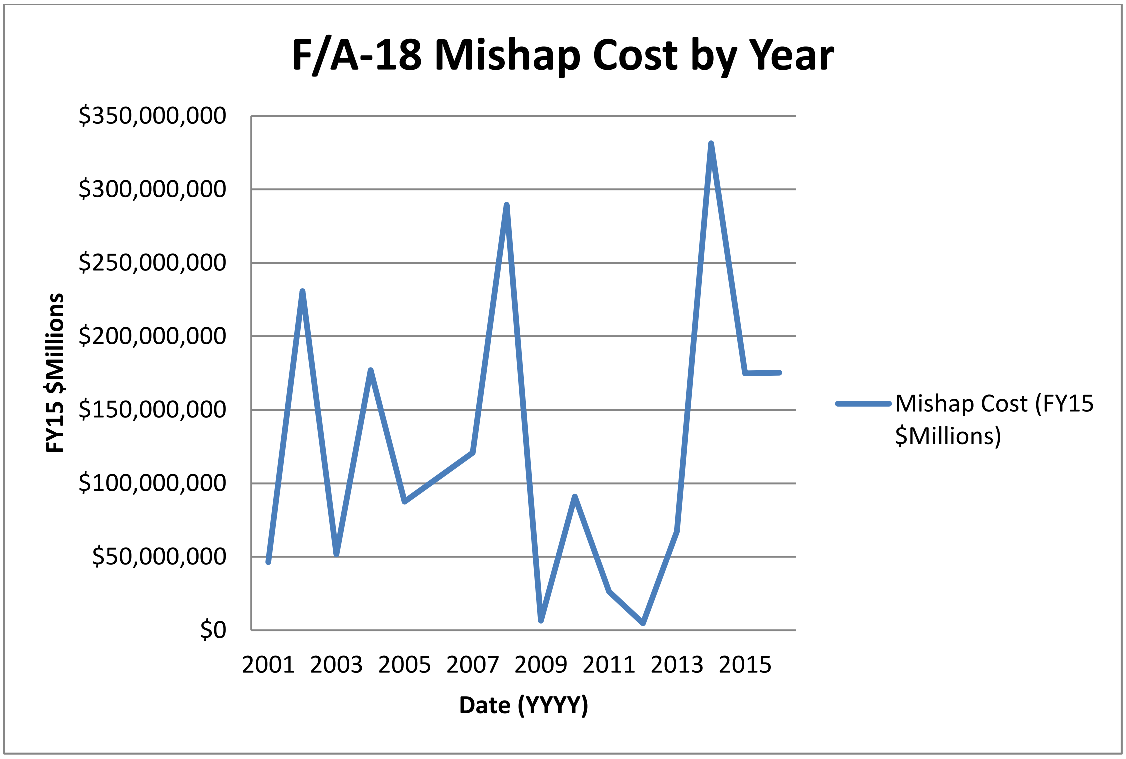

Figure 2 Total Cost of All Mishaps per Year (FY15 $Millions).

2. DECKPLATE Data

The Naval Air Systems Command maintains all of its maintenance data for hornet squadrons in a database known as the Decision Knowledge Programming for Logistics Analysis and Technical Evaluation (DECKPLATE) (DON, 2017). For the purposes of this study, squadron monthly maintenance data evaluated included:

1. # of sorties
2. # of flight hours
3. # of ship-board sorties
4. # of ship-board flight hours
5. Type/Model/Series (T/M/S) of aircraft flown
6. Squadron

A total of 5,728 discrete squadron months were evaluated for the various 36 operational squadrons. Figure 3 shows a graphical representation of total sorties and total flight hours over time. Of note, not all squadrons had the same number of monthly

maintenance data due to some of them transitioning to the Super Hornet after September 1, 2001, or being disestablished after September 1, 2001. Numbers and sorties increase until 2012 as more squadrons transition from flying the F-14 Tomcat to flying the F/A-18 Super Hornet. Since 2012, sorties and flight hours have both decreased due to a combination of the drawdown in the wars in Iraq and Afghanistan and budgetary constraints.

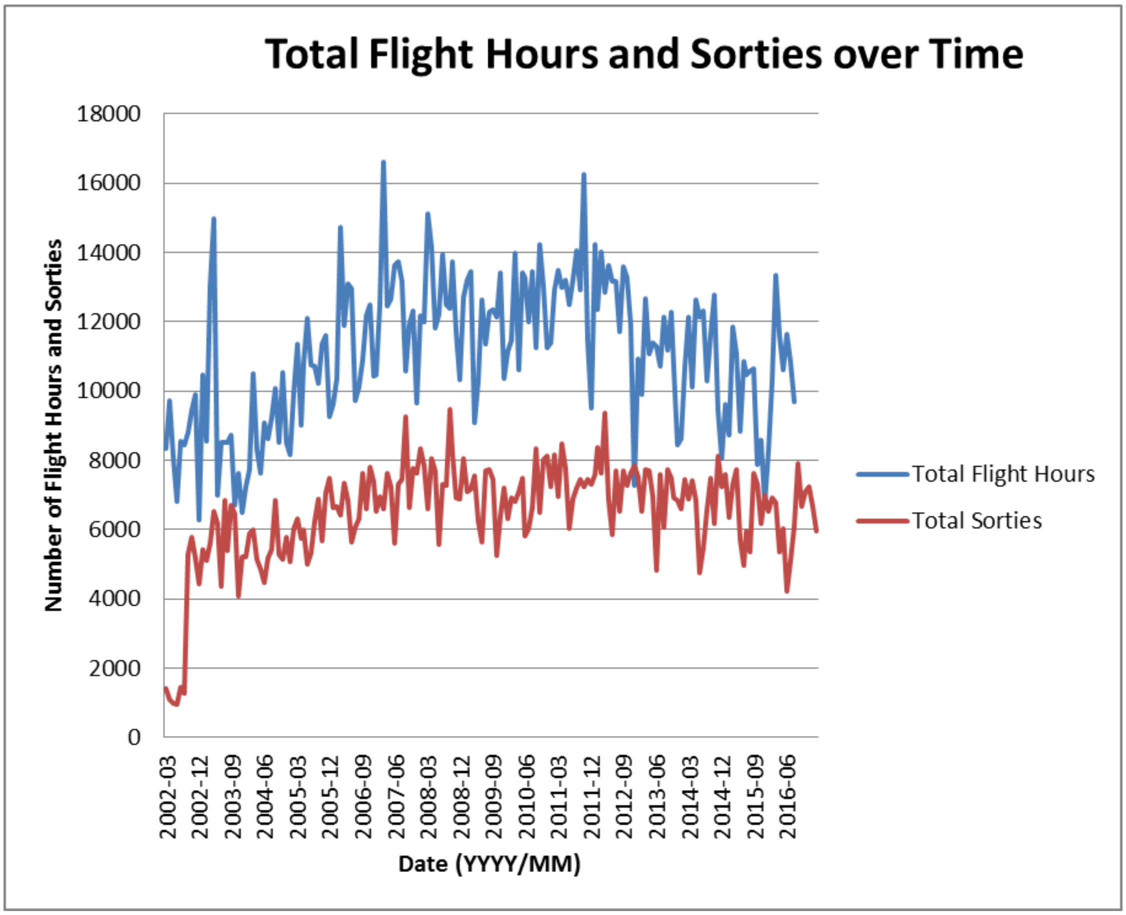

Figure 3 Graphical Representation of DECKPLATE Data over Time.

G. ANALYZING THE POPULATION

In an effort to refine the analysis, the data was first used descriptively to deduce the data population-mishap rate per 100,000 flight hours and the population-mishap costs. This was done by adding up all of the mishaps and flight hours and dividing them by 100,000. Table 3 Tables 3 and 4 show the population results.

Table 3 Sortie/Flight Hour/Mishap Population Data Summary (FY15 $).

Population	Months	Sorties	Flight Hours	Class A	Class B	Class C	Total
	5728	1,169,756	1,940,931	39	53	170	262
FM				38	42	117	197
FRM				1	7	12	20
AGM				0	4	41	45
Cost				$1,924,398,946	$38,645,858	$23,001,918	$1,986,046,723
Avg Cost				$49,343,562.73	$729,167.14	$135,305.40	$7,580,331

Table 4 Mishaps per 100,000 Flight Hours by Classification and Severity.

Population	Total	Class A	Class B	Class C
	13.50	2.01	2.73	8.76
FM		1.96	2.16	6.03
FRM		0.05	0.36	0.62
AGM		0.00	0.21	2.11

A few details can be gleaned from these population results. First, mishaps during the 15 timeframe analyzed occurred at a rate of 13.50 per 100,000 flight hours. Second, more severe mishaps are less likely to happen and cost more when they do happen, with the average cost of Class A, B, and C mishaps being $49,343,563, $729,167, and $135,305 respectively in FY 2015 dollars.

H. DATA ANALYSIS

After conducting the literature review two trends stood out as potentially influential mishap indicators. Specifically that:

- Recent pilot flight hours affect mishap rates.
- Change in execution can affect performance in individuals, regardless of experience level.

These trends informed the structures with which to further analyze the data. Mishap cost would be analyzed as a function of previous flight hours, specifically the previous month's, previous three months', and previous six months' flight hours. Previous studies done by the Navy have shown that pilot flight hours flown in the past 30

days have an effect on PCF mishap rates. My experience as a naval aviator leads me to believe that flight hours flown over three and six months are also an important indicator of pilot and squadron level proficiency. One, three, and six months were chosen in order to have a range of lag structures to analyze for significance.

Additionally, in order to attempt to capture any affect that a change in flight hours had on mishap cost, a ratio reflecting the change in flight hours from the previous two quarters would be measured.

I. MODEL DEVELOPMENT

In an attempt to develop a predictive tool, four models were chosen for the reasons above, developed, and analyzed for statistical significance. The models utilized multivariate linear regression with Mishap Cost as the dependent variable. The models varied by the selection of the independent variables:

1. Previous month's sorties and flight hours
2. Previous three months' sorties and flight hours
3. Previous six months' sorties and flight hours
4. Ratio of Previous Quarter's Flight Hours / Two Quarters Past Previous Flight Hours

Control variables included:

1. Squadron
2. Type / Model / Series of Aircraft
3. Mishap Severity
4. Percent Shipboard Flight Hours

An equation form of the regression analysis for the Previous Month's Flight Hours example is:

$$Y= aX_1 + bX_2+ cX_3+ dX_4+ e X_5+ f X_6$$

Y = Mishap Cost

X_1 = Squadron

X_2 = Percent Shipboard Flight Hours

X_3 = Type / Model / Series of Aircraft

X_4 = Mishap Severity

X_5 = Previous Month's Sorties

X_6 = Previous Month's Flight Hours

The statistical analysis program STATA was used to generate the results and check for statistical significance. A result was determined to be statistically significant if Prob> F for the regression was $\leq .05$ and if the independent variable analyzed passed a p-test of $\leq .05$.

These models were then used to answer the primary and first secondary research questions. The primary question would be answered if previously flown flight hours can be shown to have a statistically significant effect on Mishap Cost. If more than one model is statistically significant, then the models would be analyzed to select the best-fit in order to answer the second research question of lag structure.

J. SECONDARY ANALYSIS

With a statistically significant model and best fit lag structure selected; this section analyzes the financial and operational implications of the model.

1. Operational Implications / Mishap Rates

For the pertinent independent variable, the data is separated into three different segments: $< .5\ \sigma$, $> .5\ \sigma$, within $.5\ \sigma$ of the mean, providing three segments of analysis: a "low" flight hour, a "normal" flight hour (average, and within average deviation), and a "high" flight hour. After separation the data was then analyzed to find the mishap rates for each segment and mishap severity. These mishap rates were then compared to the population mishap rates in Table 3in order to evaluate any trends and operational implications.

2. Financial Implications

This section analyzes a theoretical example of budgetary savings that the DON receives by reducing an operational hornet squadron from its normal non-deployed flight hour level to the THD. The additional mishap cost associated with the model developed

above is then added to the theoretical budgetary savings to discover the financial implications of a relationship between aviation mishap cost and previously flown flight hours.

a. Cost Savings of a Reduction to THD

COMNAVAIRFORINST 3510.11A delineates the Type/Model/Series readiness and resource standards for naval air force units. In enclosure 1, specific flight hour requirements during each phase of a squadron's work-up cycle and deployment are listed. When in the maintenance phase of the work-up cycle for deployment, F/A-18 squadrons are typically funded at a 50 percent Training and Readiness (T&R) standard. Funding at 50 percent T&R represents funding for 229.5 flight hours a month for a typical 17-pilot F/A-18 squadron (DON, 2010). A reduction to 11 flight hours a month per pilot results in 187 flight hours per month. This means that there is a total reduction of 42.5 flight hours per month for a typical 17 pilot F/A-18 squadron in the maintenance phase when reduced to the THD.

Fixed Wing reimbursable rates are calculated by the DOD and published yearly. The FY 2015 reimbursable rates for F/A-18 hornets and super-hornets are located in Table 5.

Table 5 FY 2015 Fixed Wing Reimbursable Rates. Source: Roth, 2014

	Other DOD Component User Rate
F/A-18A	$10,564
F/A-18C	$10,624
F/A-18D	$12,744
F/A-18E	$10,079
F/A-18F	$9,954

The reimbursable rates in Table 55 are used as a baseline to calculate projected cost savings from a reduction in flight hours to the THD. Cost per Hour (CPH) is divided into four separate categories and approximate percentages as defined by Simpson are delineated below (2015):

- 39 percent—Fuel: The fuel cost associated with the flying hour

- 15 percent—Consumables: Items used to sustain or repair aircraft. The residual cost incurred as periodic maintenance is performed.
- 45 percent—Repairables: Aircraft components that are repaired and returned to the supply system. Again, part of the residual cost incurred as periodic maintenance is performed.
- <1 percent—Contracts: Fixed cost associated with labor contracted to sustain aircraft.

For an F/A-18E squadron, based on the above data, a reduction of 42.5 hours would net $428,358.5 in savings if the full reimbursable rate is used in the calculation. However, if only fuel and consumables are believed to be saved then a reduction of 42.5 hours would net $231,313 in savings.

These theoretical savings are analyzed with regards to mishap cost and likelihood of a mishap if one of the independent variables is found to be significantly correlated to mishap cost.

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IV. RESULTS

Results are broken down into two separate parts. First, the statistical results of the model formulation is displayed, to answer the primary research question about mishap costs. Second, a post hoc analysis is completed on the most significant independent variable of the regression analysis to further investigate the results obtained in answering the primary question. This post hoc analysis includes a discussion of the mishap rates per 100,000 flight hours for varying flight hour segments and financial implications of the model.

A. MODEL ANALYSES

Multivariate linear regressions on mishap costs were performed in STATA utilizing the procedure outlined in Chapter 3. An alpha of 0.05 was used to test for statistical significance in all cases, but p-values are reported for completeness. The full STATA results are located in Appendix B.

1. Mishap Cost as a Linear Function of Previous Month's Sorties and Flight Hours

$$\text{Prob} > F = 0.000$$
$$R^2 = 0.3269$$
$$\text{Adj } R^2 = 0.3084$$

Table 6 Partial STATA Results for Previous Month's Sorties and Flight Hours Regression.

Mishap Cost (FY 15 $)	Coef.	Std. Err.	P>|t|
Squadron	74812.76	139065.5	0.591
T/M/S	1591419	1782064	0.373
Category	-1020796	1909698	0.593
Severity	-2.01E+07	1953095	0.000
P1MSBFH	-242272.2	3551230	0.946
P1MS	56828.24	27816.61	0.042
P1MFH	-10812.99	10131.59	0.287

Overall, the regression in Table 6 can be said to predict the dependent variable. However, only 32.69 percent of the variance can be attributed to the independent

variables. The only coefficients that are statistically different from 0 are mishap severity and previous month's sorties.

2. Mishap Cost as a Linear Function of Previous Three Months' Sorties and Flight Hours

Prob > F = 0.000
$R^2 = 0.3261$
Adj $R^2 = 0.3075$

Table 7 Partial STATA Results for Previous Three Months' Sorties and Flight Hours Regression.

Mishap Cost (FY 15 $)	Coef.	Std. Err.	P>|t|
Squadron	65975.14	139105.1	0.636
T/M/S	2147054	1785627	0.230
Category	-1075740	1910543	0.574
Severity	-2.00E+07	1937652	0.000
P3MSBFH	1965462	3945648	0.619
P3MS	22067.46	12641.49	0.082
P3MFH	-9551.781	4470.612	0.034

Overall, the regression in Table 7ble 7 can be said to predict the dependent variable. However, only 32.61 percent of the variance can be attributed to the independent variables. The only variables that are statistically different from 0 are mishap severity and previous three months' flight hours. A negative coefficient of -9,551.78, implies that for every additional flight hour flown in the previous three months that mishap cost would decrease by $9,551.78, if a mishap occurred.

3. Mishap Cost as a Linear Function of Previous Six Months' Sorties and Flight Hours

Prob > F = 0.000
$R^2 = 0.3285$
Adj $R^2 = 0.3099$

Table 8 Partial STATA Results for Previous Six Months' Sorties and Flight Hours Regression.

Mishap Cost (FY 15 $)	Coef.	Std. Err.	P>|t|
Squadron	56523.69	139232.5	0.685
T/M/S	2504468	1791706	0.163
Category	-867354.7	1901513	0.649
Severity	-2.02E+07	1939949	0.000
P6MSBFH	2183197	4591289	0.635
P6MS	7819.252	7390.563	0.291
P6MFH	-6300.37	3001.086	0.037

Overall, the regression in Table 8 can be said to predict the dependent variable. However, only 32.85 percent of the variance can be attributed to the independent variables. The only variables that are statistically different from 0 are mishap severity and previous six months' flight hours. A negative coefficient of -6,300.37, implies that for every additional flight hour flown in the previous six months that mishap cost would decrease by $6,300.37, if a mishap occurred.

4. Mishap Cost as a Linear Function of Ratio of (Previous Quarter's Flight Hours) / (Two Quarters Past Previous Flight Hours).

Prob > F = 0.000
$R^2 = 0.3241$
Adj $R^2 = 0.3082$

Table 9 Partial STATA Results for Ratio of (Previous Quarter's Flight Hours) / (Two Quarters Past Previous Flight Hours Regression).

Mishap Cost (FY 15 $)	Coef.	Std. Err.	P>|t|
Squadron	58328.81	139078.3	0.675
T/M/S	1781377	1770914	0.315
Category	-414109.3	1877435	0.826
Severity	-2.01E+07	1937755	0.000
PD1QS	4632560	3657743	0.206
PD1QFH	-2515362	3576831	0.483

Overall, the regression in Table 9 can be said to predict the dependent variable. However, only 32.41 percent of the variance can be attributed to the independent variables. The only variable that is statistically different from 0 is mishap severity.

B. LAG STRUCTURE

Two of the models showed a statistically significant relationship between flight hours and mishap cost: previous three months' flight hours and previous 6 months' flight hours. A comparison of p-values of both sorties and flight hours shows that the p-value for previous three months' flight hours is the lowest at 0.034 and that model is used to answer the secondary research questions. The p-value for the previous six months' flight hours is higher at 0.037 and suggests that a six-month time period reduces explanatory power. The results suggest that a squadron's previous three months flight hour data should be used in order to predict potential mishap cost. The operational and financial implications are covered in the following sections.

C. MISHAP RATES

Aviation mishap rate is used to further investigate the operational implications of the previous three months' flight hour model. Mishap rates per 100,000 flight hours for the population of 5,728 months are detailed in Tables 3 and 4. Appendix C details the detailed mishap cost breakdown per segment of flight hours: low, normal, and high. For the previous three months' flight hour data set the segments are broken down accordingly (as explained in the previous chapter, these thresholds were arbitrarily set so that the "normal" category contains the mean plus or minus 0.5 standard deviation: that is, the normal contains the average, and the observations with an average amount of variance.):

- Low Flight Hours: < 730.45 flight hours in the previous three months
- Normal Flight Hours: Between 730.45 and 1212.11 flight hours in the previous three months
- High Flight Hours: > 1212.11 flight hours in the previous three months

Additionally, mishap rates are compared to the population data as well as for a sample that only includes data where there was <10 percent shipboard flight hours in the

previous three months. A data point with <10 percent shipboard flight hours provides an indication of any differences between deployed and ashore flight hours. While shipboard flight hours were not shown to be statistically significant *on average* in the model developed above, due to the different natures of deployed and non-deployed operations it may prove useful to analyze this sample of the population, bifurcated to separate the observations with very few (less than 10 percent) shipboard flight hours.

A stoplight chart is used to determine values that are greater than or less than 25 percent of the population values. That is, if a value is greater than 125 percent of the population mishap rate in Table 10 then the cell will be shaded red. While if a value is less than 75 percent of the population mishap rate in Table 10 10, then the cell will be shaded green. Otherwise, a cell will remain unshaded. The 25 percent threshold was selected arbitrarily, consistent with the author's observations of similar charts, before the data were tabulated and the results were known.

Table 10 Population Mishap Rates by Severity per 100,000 Flight Hours.

Mishap Rates	**Total**	**Class A**	**Class B**	**Class C**
Population	13.50	2.01	2.73	8.76

Table 11 Mishap Rate Stoplight Chart by Severity and Segment for Previous Three Months' Flight Hours.

Segment	**Previous 3 Months Flight Hours**	**Total**	**Class A**	**Class B**	**Class C**
Low	**< 730.45**	18.31	2.42	4.04	11.85
Normal	**730.45 – 1212.11**	13.09	2.04	2.76	8.28
High	**> 1212.11**	11.16	1.69	1.86	7.61

Table 11 shows that in the low flight-hour segments that mishap rates increased >25 percent in total and for Class B and Class C mishaps. Mishap rates in the normal flight hour segment also increased, but not above 25 percent. This information is consistent with the model developed above, in that as mishap rates increase one would expect mishap costs to also increase.

Table 12 Mishap Rate Stoplight Chart by Severity and Segment for Previous Three Months' Flight Hours with <10 percent Shipboard Flight Hours

Segment	Previous 3 Months Flight Hours	Total	Class A	Class B	Class C
Low	**< 730.45**	19.42	2.77	4.36	12.28
Normal	**730.45 – 1212.11**	27.12	4.24	5.72	17.16
High	**> 1212.11**	10.34	2.07	1.03	7.24

Table 12 shows that in the low and normal flight hour segments that mishap rates increased >25 percent in total and for all mishap classes. Notably, the total mishap rate for normal fight hour operations in the previous three months is over double the population mishap rate of 13.50. This information is not consistent with the model above, but does perhaps indicate that deployed and non-deployed squadrons behave differently, with regards to mishap rates.

D. MISHAP COST PER FLIGHT HOUR

By reducing a typical hornet squadron's flight hours from 50 percent T&R to the THD for three months would save approximately $428,000 in operating costs. The coefficient of flight hours in the previous three months' flight hour model was -9550. If one compared the coefficient to the reimbursable fixed wing rate for an F/A-18E of $10,079 then one could see that even if a mishap were to occur, the model implies that the reduction in cost of reducing a flight hour would be roughly equal to the cost per flight hour. Without further analysis, the results of this analysis would not support an increase in flight hours to reduce overall costs. Non-cost benefits that might accrue to additional flight hours, such as increased readiness, are of course not a part of this analysis.

E. EFFECT OF SEVERITY CLASSIFICATION ON MISHAP COST

Severity classification (A/B/C) was found to be a statistically significant variable across all models. This may be due to the nature of how severity is calculated, in that the severity classifications are closely tied to mishap cost. To analyze severity's effect on the regression analyses a post-hoc regression was conducted with severity removed from the previous three months' flight hours' regression. The equation is shown below:

$$Y = aX_1 + bX_2 + cX_3 + dX_4 + e X_5$$

Y = Mishap Cost

X_1 = Squadron

X_2 = Percent Shipboard Flight Hours

X_3 = Type / Model / Series of Aircraft

X_4 = Previous Three Months' Sorties

X_5 = Previous Three Months' Flight Hours

1. Mishap Cost as a Linear Function of Previous Three Months' Sorties and Flight Hours (Severity Removed)

Prob > F = 0.0699
R^2 = 0.0444
Adj R^2 = 0.0219

Table 13 Partial STATA Results for Mishap Cost as a Linear Function of Previous Three Months' Sorties and Flight Hours (Severity Removed)

Mishap Cost (FY 15 $)	Coef.	Std. Err.	P>|t|
Squadron	92709	165294.5	0.575
T/M/S	1989870	2122100	0.349
Category	-6246365	4682932	0.005
P3MSBFH	4085745	15006.55	0.384
P3MS	28366	5310.1	0.06
P3MFH	-11128.56	926502	0.037

The results from STATA in Table 14 show that without severity the model is not statistically significant at the 0.05 level of significance. However, the 0.05 threshold is arbitrary (Dahiru, 2008) and for example, the most recent American Psychological Association (APA) manual guidelines for reporting statistics have recommended reporting exact p-values, and avoiding arbitrary significance distinctions for this reason. The p-value of 0.0699 for the overall model indicates that there is about a 7% chance that the results we are reporting are due to random chance, and not the actual fit of the model (not remarkably different from a 5% chance). The p-value and coefficient for previous three months' flight hours is similar to the analysis with severity in the model, and may still be interpreted, with the cautionary note that the results are slightly more likely to be due to chance alone than is desirable. In sum, this post hoc analysis with severity

removed as an independent variable shows a potential limitation with the model used, and further research may need to be conducted to determine the affect severity has upon mishap cost.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

Aviation mishaps will always be an unfortunate part of naval aviation. Only by understanding some of the relating issues with mishaps can they hope to be decreased. Recently, there has been an increase in the number of mishaps, potentially due to budgetary restrictions on flight hours. Luckily, mishaps are relatively rare occurrences and the most severe mishaps even more rare. By taking a squadron level approach this thesis has attempted to analyze at a macro level the effect flight hours have on mishap cost.

Flight hours are one of the main resources that the Navy uses to prepare a squadron for deployment. For non-deployed squadrons they are also one of the first resources to be reduced in a tight fiscal environment. This thesis has shown that there is a correlation between previously flown flight hours, for a three and six months' time period, and mishap cost. Understanding how the level of flight hours affects a squadron's mishap rate and the cost of those mishaps should provide decision makers with better information when difficult budgetary decisions are made.

B. CONCLUSIONS

The primary research question has been answered in the affirmative. Using linear multivariate analysis, mishap costs are correlated to previously flown flight hours in the three and six months' time frame. The models developed accounted for approximately 32 percent of the variance of mishap cost. The operational implications are that mishap costs do increase during periods of low flight hour operation, and are slightly reduced during periods of high flight hour operation. Post hoc analysis suggests this may be correlated with an increase in mishap rates as flight hours decrease. This implies that the number of flight hours a squadron has previously flown is a determinant in that squadron's potential for a mishap.

We found no significant relationship between mishap cost and several control variables: squadron, type/model/series of aircraft, the rate of change of flight hours,

number of sorties in the past three/six months, and the percentage of shipboard flight hours across all lag structures.

C. LIMITATIONS

This study utilized severity as an independent variable in order to determine a relationship to mishap cost. Severity and mishap cost are closely related and this may have influenced the overall fit of the model, and so results must be interpreted with caution. However, both the coefficient and p-value for previous three months flight hours was similar to the equation with severity class included.

D. RECOMMENDATIONS AND FUTURE RESEARCH

This analysis was done on a dataset containing mishaps. Findings then should be interpreted as providing cost estimates for mishaps *given that an accident occurs*. Due to the relative infrequent nature of mishaps and the relatively low coefficient found during the model, previously flown flight hours may not significantly fiscally impact the DON. However, looking at the human side, a reduction in flight hours may not be desirable due to a potential for decreased morale and retention in the squadron. Additionally, flight hours are used as a measure to increase readiness during the work-up cycle for deployment, and a reduction in flight hours may correspond to a reduction in readiness. Future research should examine these non-cost implications.

Although post hoc analysis indicated the results need to be interpreted with caution, sufficiently strong evidence exists to make limited recommendations. During periods of flying operations below normal, squadron commanding officers and safety officers should be briefed on the historically higher mishap rates and costs that appear to be associated with reduced operational tempo. This will better inform commanding officers of the potential dangers of a reduction in squadron flight hours. Safety officers may be able to implement squadron level safeguards to mitigate the effects of a reduction in flight hours. Further research should be conducted on the best ways to mitigate increased mishap costs and rates associated with periods of reduced flying hours. Mishap rates have been shown to increase in squadrons with <10 percent of their flight hours

onboard a ship. Future research should be conducted in order to establish the causal factor behind this relationship.

Further research should also be undertaken to evaluate different platforms in naval aviation. The establishment of a trend between mishap cost and previously flown flight hours across platforms would be a powerful tool for future decision making.

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APPENDIX A. INJURY COST GUIDELINES

Injury cost guidelines are delineated in OPNAVINST 5102.1D (2005) and are computed for injuries, fatalities, and occupational illnesses. Table 14 details the injury costs in FY 2004 dollars:

Table 14 Injury Cost Standards Table (FY2004 dollars)

	No Lost Time (per Case)	**Days Hospitalized (per Day)**	**Lost Time Case (per Day)**	**Permanent Partial Disability**	**Permanent Total Disability**	**Fatality**
Flying Officer	$187	$2,000	$1,300	$1,300,000	$1,300,000	$1,300,000
Other Officers	$187	$2,000	$1,100	$300,000	$850,000	$850,000
Enlisted Personnel, Cadets	$187	$2,000	$800	$250,000	$500,000	$500,000[1] $270,000[2]
Civilian Employees	$187	$2,000	$800	$250,000	$385,000	$460,000
Other	$187	$2,000	$400	$180,000	$390,000	$270,000

[1] Non-flight crewmember fatalities

[2] Flight crewmember fatalities

Source: OPNAVINST 5102.1D (2005) Glossary G-3

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APPENDIX B. STATA MULTIVARIATE REGRESSION VARIABLES AND RESULTS

A. STATA VARIABLES

MisCost15 = Mishap Cost in FY 2015 Dollars

VFA = Squadron
ABCDEF = Type/Model/Series of Aircraft
Cat = Mishap Category (FM/FRM/AGM)
Sev = Mishap Severity (A/B/C)

P1MS = Previous Month's Sorties
P1MFH = Previous Month's Flight Hours
P1MSBFH = Previous Month's Shipboard Flight Hours

P3MS = Previous Three Months' Sorties
P3MFH = Previous Three Months' Flight Hours
P3MSBFH = Previous Three Months' Shipboard Flight Hours

P6MS = Previous Six Months' Sorties
P6MFH = Previous Six Months' Flight Hours
P6MSBFH = Previous Six Months' Shipboard Flight Hours

P1DQS = Previous Quarter's Sorties / Two Quarters ago Sorties
P1DQFH = Previous Quarter's Flight Hours / Two Quarters ago Flight Hours

B. STATA RESULTS

Table 15 STATA Regression Results for Previous Month's Sorties and Flight Hours.

Source	SS	df	MS
Model	6.16E+16	7 8.80	4.90E+16
Residual	1.27E+17	254 4.99	5.90E+15
Total	1.89E+17	261 7.22	3.40E+15

Number of obs	262
F(7, 254)	17.62
Prob > F	0
R-squared	0.3269
Adj R-squared	0.3084
Root MSE	22000000

MisCost15	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
VFA	74812.76	139065.5	0.54	0.591	-199055.5	348681
ABCDEF	1591419	1782064	0.89	0.373	-1918085	5100923
Cat	-1020796	1909698	-0.53	0.593	-4781654	2740063
Sev	- 2.01E+07	1953095	-10.27	0	-2.39E+07	- 1.62E+07
P1MSBFH	- 242272.2	3551230	-0.07	0.946	-7235877	6751333
P1MS	56828.24	27816.61	2.04	0.042	2047.664	111608.8
P1MFH	- 10812.99	10131.59	-1.07	0.287	-30765.61	9139.634
_cons	4.50E+07	8387792	5.37	0	2.85E+07	6.15E+07

Table 16 STATA Regression Results for Three Previous Months' Sorties and Flight Hours.

Source	SS	df	MS
Model	6.15E+16	7 8.78	2.70E+16
Residual	1.27E+17	254 5.00	2.00E+15
Total	1.89E+17	261 7.22	3.40E+15

Number of obs	262
F(7, 254)	17.56
Prob > F	0
R-squared	0.3261
Adj R-squared	0.3075
Root MSE	22000000

MisCost15	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
VFA	65975.14	139105.1	0.47	0.636	-207971.1	339921.4
ABCDEF	2147054	1785627	1.2	0.23	-1369467	5663575
Cat	-1075740	1910543	-0.56	0.574	-4838263	2686784
Sev	- 2.00E+07	1937652	-10.3	0	-2.38E+07	- 1.62E+07
PP3MSBH	1965462	3945648	0.5	0.619	-5804889	9735814
P3MS	22067.46	12641.49	1.75	0.082	-2828.023	46962.94
P3MFH	- 9551.781	4470.612	-2.14	0.034	-18355.97	- 747.5916
_cons	4.73E+07	8971105	5.27	0	2.96E+07	6.49E+07

Table 17 STATA Regression Results for Six Previous Months' Sorties and Flight Hours.

Source	SS	df	MS
Model	6.19E+16	7 8.84	6.20E+16
Residual	1.27E+17	254 4.98	4.50E+15
Total	1.89E+17	261 7.22	3.40E+15

Number of obs	262
F(7, 254)	17.75
Prob > F	0
R-squared	0.3285
Adj R-squared	0.3099
Root MSE	22000000

MisCost15	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
VFA	56523.69	139232.5	0.41	0.685	-217673.5	330720.9
ABCDEF	2504468	1791706	1.4	0.163	-1024023	6032959
Cat	- 867354.7	1901513	-0.46	0.649	-4612094	2877385
Sev	- 2.02E+07	1939949	-10.39	0	-2.40E+07	- 1.63E+07
PP6MSBH	2183197	4591289	0.48	0.635	-6858647	1.12E+07
P6MS	7819.252	7390.563	1.06	0.291	-6735.334	22373.84
P6MFH	-6300.37	3001.086	-2.1	0.037	-12210.55	-390.188
_cons	5.37E+07	9429926	5.69	0	3.51E+07	7.23E+07

Table 18 STATA Regression Results for Ratio of Previous Quarter's Flight Hours / Two Quarters Past Previous Flight Hours.

Source	SS	df	MS
Model	6.11E+16	6 1.01	8.30E+17
Residual	1.27E+17	255 4.99	7.20E+15
Total	1.89E+17	261 7.22	3.40E+15

Number of obs	262
F(6, 255)	20.38
Prob > F	0
R-squared	0.3241
Adj R-squared	0.3082
Root MSE	22000000

MisCost15	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
VFA	58328.81	139078.3	0.42	0.675	-215559.6	332217.3
ABCDEF	1781377	1770914	1.01	0.315	-1706102	5268855
Cat	- 414109.3	1877435	-0.22	0.826	-4111362	3283143
Sev	- 2.01E+07	1937755	-10.37	0	-2.39E+07	- 1.63E+07
PD1QS	4632560	3657743	1.27	0.206	-2570672	1.18E+07
PD1QFH	-2515362	3576831	-0.7	0.483	-9559252	4528529
_cons	5.02E+07	7855528	6.39	0	3.47E+07	6.57E+07

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APPENDIX C. COMPLETE BREAKDOWN OF MISHAPS, FLIGHT HOURS, AND COST DATA.

A. PREVIOUS THREE MONTHS' FLIGHT HOURS

Mean - 0.5 σ = 730.45 Flight Hours

Mean + .5 σ = 1212.11 Flight Hours

Table 19 Previous Three Months' Flight Hours Mishaps and Cost.

P3MFH	Months	Sorties	Flight Hours	Class A	Class B	Class C	Total
< 730.45	1551	262,456	371,345	9	15	44	68
FM				9	13	34	56
FRM				0	1	4	5
AGM				0	1	6	7
Cost				$505,364,510	$9,846,477	$5,702,727	$520,913,714
Avg Cost				$56,151,612	$656,432	$129,607	$7,660,496
> 1212.11	1246	267,498	591,402	10	11	45	66
FM				10	8	25	43
FRM				0	3	3	6
AGM				0	0	17	17
Cost				$427,753,178	$7,360,479	$5,097,554	$440,211,211
Avg Cost				$42,775,318	$669,134	$113,279	$6,669,867
730.45 – 1212.1	2931	639,802	978,183	20	27	81	128
FM				19	21	58	98
FRM				1	3	5	9
AGM				0	3	18	21
Cost				$991,281,258	$21,438,902	$12,201,637	$1,024,921,797
Avg Cost				$49,564,063	$794,033	$150,637	$8,007,202

Table 20 Previous Three Months' Flight Hours Mishap Rates per 100,000 Flight Hours.

P3MFH	**Total**	**Class A**	**Class B**	**Class C**
< 730.45	18.31	2.42	4.04	11.85
FM		2.42	3.50	9.16
FRM		0.00	0.27	1.08
AGM		0.00	0.27	1.62
> 1212.11	11.16	1.69	1.86	7.61
FM		1.69	1.35	4.23
FRM		0.00	0.51	0.51
AGM		0.00	0.00	2.87
730.45 – 1212.11	13.09	2.04	2.76	8.28
FM		1.94	2.15	5.93
FRM		0.10	0.31	0.51
AGM		0.00	0.31	1.84

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